Attorney Docket No. ISOT-017

APPLICATION

FOR UNITED STATES LETTERS PATENT

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, **Paul A. Knight**, a citizen of Canada, have invented a new and useful spray coolant reservoir system of which the following is a specification:

Spray Coolant Reservoir System

CROSS REFERENCE TO RELATED APPLICATIONS

Not applicable to this application.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable to this application.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to spray thermal management systems for thermally managing electronic devices and more specifically it relates to a spray coolant reservoir system for increasing the efficiency and performance of a spray thermal management system.

Description of the Related Art

Modern electronic devices have increased thermal management requirements. Conventional dry thermal management technology (e.g. fans, vents) simply is not capable of efficiently cooling modern high-end electronics.

Spray thermal management technology is being adopted today as the most efficient option for thermally managing electronic systems. United States Patent No. 5,220,804 entitled High Heat Flux Evaporative Spray Cooling to Tilton et al. describes the earlier versions of spray technology. United States Patent No. 6,108,201 entitled Fluid Control Apparatus and Method for Spray Cooling to Tilton et al. also describes the usage of spray technology to cool a printed circuit board. Spray thermal management may be performed locally (i.e. where the chip is sprayed directly), globally (i.e. where the chip and surrounding electronics/boards are also sprayed), a combination of locally and globally, or in conjunction with air cooling or other cooling methods.

One problem with conventional spray technology is that excess coolant is often times retained within the spray chamber to ensure adequate coolant return flow to the pump and to compensate for any coolant leakage. This excess coolant can interfere with the thermal management of electronic devices within the spray chamber. In addition, this excess coolant can also directly impact and damage the electronic components during attitude changes, deceleration and acceleration of the spray chamber.

Another problem with conventional spray technology is that prior to accessing the spray chamber the coolant must be drained which can lead to contamination and coolant loss. A further problem with conventional spray technology is that during acceleration, deceleration and attitude change, temporary coolant loss to the pump may occur thereby decreasing the efficiency of the spray system. Another problem with

conventional spray technology is that the pressure within the spray chamber varies greatly and is typically dependent solely upon the evaporation of coolant, volume of coolant in spray chamber and temperature within the spray chamber without adequate control. Another problem with conventional spray technology is that if a leak within the spray system exists there is no automatic method for adding additional coolant to the spray system to compensate for the coolant loss. A further problem with conventional spray technology is that the seal of the spray chamber typically must be broken to fill or add coolant.

While these devices may be suitable for the particular purpose to which they address, they are not as suitable for increasing the efficiency and performance of a spray thermal management system. In these respects, the spray coolant reservoir system according to the present invention substantially departs from the conventional concepts and designs of the prior art, and in so doing provides an apparatus primarily developed for the purpose of increasing the efficiency and performance of a spray thermal management system.

BRIEF SUMMARY OF THE INVENTION

In view of the foregoing disadvantages inherent in the known types of spray thermal management systems now present in the prior art, the present invention provides a new spray coolant reservoir system construction wherein the same can be utilized for increasing the efficiency and performance of a spray thermal management system.

The general purpose of the present invention, which will be described subsequently in greater detail, is to provide a new spray coolant reservoir system that has many of the advantages of the spray thermal management systems mentioned heretofore and many novel features that result in a new spray coolant reservoir system which is not anticipated, rendered obvious, suggested, or even implied by any of the prior art spray thermal management systems, either alone or in any combination thereof.

To attain this, the present invention generally comprises a reservoir capable of storing a volume of coolant, a chassis with a spray chamber, a pump unit, an intake valve fluidly connected to the pump unit for providing coolant from the reservoir or the spray chamber, an output valve fluidly connected to the pump unit for controlling coolant flow from the pump unit to either the spray unit or the reservoir. The reservoir preferably includes a vent port, a fill port, and a chamber port. The chamber port is fluidly connected to the spray chamber for allowing control of the internal pressure within the spray chamber.

There has thus been outlined, rather broadly, the more important features of the invention in order that the detailed description thereof may be better understood, and in order that the present contribution to the art may be better appreciated. There are

additional features of the invention that will be described hereinafter and that will form the subject matter of the claims appended hereto.

In this respect, before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and to the arrangements of the components set forth in the following description or illustrated in the drawings. The invention is capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology employed herein are for the purpose of the description and should not be regarded as limiting.

A primary object of the present invention is to provide a spray coolant reservoir system that will overcome the shortcomings of the prior art devices.

A second object is to provide a spray coolant reservoir system for increasing the efficiency and performance of a spray thermal management system.

Another object is to provide a spray coolant reservoir system that provides supplemental coolant to compensate for leaks within the spray thermal management system.

An additional object is to provide a spray coolant reservoir system that is capable of receiving the coolant drained from a spray chamber prior to opening the spray chamber.

Another object is to provide a spray coolant reservoir system that does not require opening of the spray chamber to fill or add coolant.

A further object is to provide a spray coolant reservoir system that provides an auxiliary coolant supply for a coolant pump.

Another object is to provide a spray coolant reservoir system that ensures an adequate coolant supply to the pump during acceleration, deceleration and attitude changes.

Another object is to provide a spray coolant reservoir system that allows for manipulation of the internal pressure of the spray chamber thereby controlling coolant vaporization within the spray chamber.

A further object is to provide a spray coolant reservoir system that is capable of creating a negative pressure within the spray chamber to reduce coolant leakage.

A further object is to provide a spray coolant reservoir system that prevents excessive fluid retention within the spray chamber.

Another object is to provide a spray coolant reservoir system that allows an individual to conveniently monitor the coolant level.

Other objects and advantages of the present invention will become obvious to the reader and it is intended that these objects and advantages are within the scope of the present invention.

To the accomplishment of the above and related objects, this invention may be embodied in the form illustrated in the accompanying drawings, attention being called to the fact, however, that the drawings are illustrative only, and that changes may be made in the specific construction illustrated and described within the scope of the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Various other objects, features and attendant advantages of the present invention will become fully appreciated as the same becomes better understood when considered in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the several views, and wherein:

FIG. 1 is a side cutaway view of the present invention with the reservoir within the chassis.

FIG. 2 is a block diagram illustrating the fluid connections and coolant flow within the present invention.

FIG. 3 is an upper perspective view of the present invention with an exposed spray chamber and with the reservoir external of the chassis.

FIG. 4 is a side view of the present invention with an exposed spray chamber.

FIG. 5 is an upper perspective view of the present invention with an exposed spray chamber.

FIG. 6 is a side view of the present invention with an internal condenser within the spray chamber.

FIG. 7 is a flowchart illustrating the coolant flow within the present invention.

FIG. 8 is a flowchart illustrating the process for reducing the spray chamber pressure.

FIG. 9 is a flowchart illustrating the process for increasing the spray chamber pressure.

FIG. 10 is a block diagram illustrating the electrical connections and communications of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

A. Overview

Turning now descriptively to the drawings, in which similar reference characters denote similar elements throughout the several views, FIGS. 1 through 10 illustrate a spray coolant reservoir system **10**, which comprises a reservoir **50** capable of storing a volume of coolant, a chassis **20** with a spray chamber **22**, a pump unit **30**, an intake valve **34** fluidly connected to the pump unit **30** for providing coolant from the reservoir **50** or the spray chamber **22**, an output valve **36** fluidly connected to the pump unit **30** for controlling coolant flow from the pump unit **30** to either the spray unit **32** or the reservoir **50**. The reservoir **50** preferably includes a vent port **42**, a fill port **46**, and a chamber port **44**. The chamber port **44** is fluidly connected to the spray chamber **22** for allowing control of the internal pressure within the spray chamber **22**.

B. Chassis

As shown in Figures 1, 3 through 6 of the drawings, the chassis **20** may have various shapes, structures and configurations. The chassis **20** illustrated in the drawings should not be interpreted to limit the scope of protection of the present invention. The chassis **20** may be freestanding or mounted into a rigid structure, such as but not limited to a network rack.

The chassis **20** includes at least one spray chamber **22** as shown in Figures 1, 3 through 6 of the drawings. The spray chamber **22** is selectively sealed by a door or panel structure which is well known in the art of spray technology.

The spray chamber **22** is designed to allow for liquid coolant to contact electronic devices such as but not limited to electronic card members **12** thereby conducting the thermal energy generated by the card members **12**. The card members

12 may be retained within a card cage **14** or similar structure for support and protection. The card members **12** positioned within the spray chamber **22** must be capable of being positioned within a dielectric coolant which is also well-known in spray technology.

C. Reservoir

As Figures 1 through 6 illustrate, a reservoir **50** is provided within the present invention. The reservoir **50** is capable of storing a volume of coolant and is fluidly connected to the coolant system. The reservoir **50** is capable of receiving excess coolant from the spray chamber **22**. The reservoir **50** is also capable of providing coolant to the spray chamber **22** when coolant levels within the spray chamber **22** fall below a specified level.

Figure 1 illustrates the reservoir **50** within the chassis **20** or the spray chamber **22**. However the reservoir **50** may be positioned external of the chassis **20** as shown in Figures 3 through 6 of the drawings.

The reservoir **50** preferably includes a fill port **46** and a drain port **48**. The fill port **46** allows for selective filling of the reservoir **50** with coolant and the drain port **48** allows for selective draining of coolant from the reservoir **50**.

The reservoir **50** preferably includes a vent port **42** as shown in Figures 1 and 3 of the drawings. The vent port **42** allows for the selective release of gas pressure within the reservoir **50**. The vent port **42** also allows for the selective entry of air into the reservoir **50**. During normal operation, the vent port **42** is preferably closed.

The reservoir **50** preferably includes a chamber port **44** fluidly connected to spray chamber **22** as shown in Figures 1, 4, 5 and 6 of the drawings. When the chamber port **44** is opened, the pressures within the spray chamber **22** and the reservoir

50 become equalized. During normal operation the chamber port **44** is preferably closed.

D. Coolant System

The coolant system is fluidly connected to the spray unit **32**, the spray chamber **22** and the reservoir **50**. The coolant system preferably provides pressurized and thermally managed coolant to the spray unit **32**. U.S. Patent Nos. 5,220,804 and 6,108,201 illustrate spray technology that may be utilized within the present invention and are hereby incorporated by reference into this application.

As shown in Figures 1 and 2 of the drawings, an intake valve **34** is fluidly connected to the coolant system for providing coolant to the coolant system. The intake valve **34** is also fluidly connected to the spray chamber **22** and to the reservoir **50** as further shown in Figures 1 and 2. A pickup valve **40** or similar device is preferably positioned within the spray chamber **22** for drawing the waste coolant out of the spray chamber **22** as shown in Figure 1 of the drawings.

The intake valve **34** diverts a coolant input flow to the coolant system from the reservoir **50** when coolant flow from the spray chamber **22** is hindered as shown in Figure 7 of the drawings. Coolant flow from the spray chamber **22** may be hindered when there is no coolant flow or reduced coolant flow from the spray chamber **22** due to various factors such as but not limited to acceleration, deceleration and attitude change. The intake valve **34** preferably allows coolant input flow to the coolant system solely from the spray chamber **22** during normal operation, and solely or jointly from the reservoir **50** when coolant flow from the spray chamber **22** is hindered.

An output valve **36** is fluidly connected to the coolant system opposite of the input valve as shown in Figures 1 and 2 of the drawings. The output valve **36** is fluidly connected to the spray unit **32** and to the reservoir **50** for providing pressurized

fluid from the coolant system to the same. The output valve **36** preferably allows coolant output flow solely to the spray unit **32** from the coolant system during normal operation. However, when excess coolant is present within the spray chamber **22**, the output valve **36** may divert the coolant output flow to the reservoir **50** to fill the reservoir **50**.

As shown in Figures 1 and 2 of the drawings, the coolant system preferably includes a pump unit **30** that is fluidly connected between the intake valve **34** and the output valve **36**. The pump unit **30** may be comprised of various well-known pump technologies.

A condenser **60** is also preferably provided that may be positioned internally or externally of the spray chamber **22** for condensing vaporized coolant. The condenser **60** is connected to a heat exchanger **70** which reduces the temperature of the condenser **60** which is well known in the art. Filters, thermal management units and related devices may also be included within the coolant system though not shown in the drawings.

E. Control Unit

As shown in Figure 10 of the drawings, a control unit **38** is provided that is in communication with the coolant system, the pump unit **30**, the intake valve **34**, the output valve **36**, the pickup valve **40**, the vent port **42**, the drain port **48**, the fill port **46**, the chamber port **44**, the heat exchanger **70**, the condenser **60**, the sensors **39** and any other related electronic device. The sensors **39** are capable of measuring various conditions such as but not limited to coolant temperature, electronic device temperature, coolant levels (in spray chamber **22** and in the reservoir **50**), coolant flow, pressure (in spray chamber **22** and in the reservoir **50**), the attitude of the chassis **20** and other related conditions.

The control unit **38** may be comprised of various electronic technologies such as but not limited to computer devices. The control unit **38** is preferably programmable and capable of receiving and transmitting data. More than one control unit **38** may be utilized with the present invention. In addition, some of the devices within the present invention may be in direct or indirect communication with one another.

F. Controlling Coolant Flow

As shown in Figure 7 of the drawings, the coolant is first drawn from the spray chamber **22** to provide a supply coolant flow to the spray unit **32**. However, if the coolant flow from the spray chamber **22** is hindered (e.g. stopped or reduced), then the coolant is drawn from the reservoir **50** until coolant flow from the spray chamber **22** is no longer hindered as shown in Figure 7 of the drawings. It is preferably to terminate the coolant flow from the spray chamber **22** when drawing coolant from the reservoir **50**, however the coolant may be drawn simultaneously from both the reservoir **50** and the spray chamber **22**.

If the spray chamber **22** has excess coolant, it is desirable to divert all or a portion of the coolant flow from the pump unit **30** to the reservoir **50** by the output valve **36** until a desired coolant level is achieved within the spray chamber **22**. Alternatively, if the coolant level within the spray chamber **22** falls below a desired level (e.g. leakage problems), all or a portion of the coolant drawn into the pump may be supplied by the reservoir **50** by the intake valve **34**.

G. Controlling Spray Chamber Pressure

1. Overview

It is desirable to control the pressure within the spray chamber **22** for various reasons. For example, a negative or reduced pressure within the spray chamber **22** will

prevent leakage through a damaged seal. Also, increased pressure within the spray chamber **22** facilitates condensing of the coolant at higher temperatures.

2. Reducing Spray Chamber Pressure

Figure 8 illustrates an exemplary process for reducing the pressure within the spray chamber **22**. First, the chamber port **44** is closed if not already closed. Second, the vent port **42** is then opened and the intake valve **34** is switched to draw fluid only from the pickup valve **40** within the spray chamber **22**. Next, the output valve **36** is switched to provide pressurized coolant from the pump unit **30** solely to the reservoir **50** only.

The pump unit **30** is then operated which draws coolant from within the spray chamber **22** and forcing the fluid into the reservoir **50**. As the coolant is drawn out of the spray chamber **22**, the pressure within the spray chamber **22** is reduced (even to the level of negative pressure). As the coolant is forced into the reservoir **50**, the vent port **42** allows the displaced gases within the reservoir **50** to escape into the atmosphere or other structure. The vent port **42** also prevents an increase in the pressure of the reservoir **50** during this process.

Once the desired reduced pressure within the spray chamber **22** has been achieved, the pump unit **30** is terminated and the vent port **42** is closed as shown in Figure 8 of the drawings. The chamber port **44** is then opened to allow for equalization of the pressures within the spray chamber **22** and the reservoir **50** as further shown in Figure 8 of the drawings.

If the coolant level within the spray chamber **22** has dropped below a desired level, coolant from the reservoir **50** may be input back into the spray chamber **22** with the chamber port **44** open to prevent an increase in pressure within the spray chamber

22 or without the chamber port **44** open. The chamber port **44** may then be closed to allow for normal operation of the present invention.

3. Increasing Spray Chamber Pressure

Figure 9 illustrates an exemplary process for increasing the pressure within the spray chamber **22**. First, the chamber port **44** is closed if not already closed. Second, the vent port **42** is then opened and the intake valve **34** is switched to draw fluid only from the reservoir **50** only. Next, the output valve **36** is switched to provide pressurized coolant from the pump unit **30** solely to the spray chamber **22** only. The coolant may be provided into the spray chamber **22** via the spray unit **32** or a direct port.

The pump unit **30** is then operated which draws coolant from within the reservoir **50** and forcing the fluid into the spray chamber **22**. As the coolant is forced into the spray chamber **22**, the pressure within the spray chamber **22** is increased. As the coolant is forced into the spray chamber **22**, the vent port **42** allows for air to enter the reservoir **50** to displace the reduced coolant thereby preventing a reduced pressure within the reservoir **50**.

Once the desired increased pressure within the spray chamber **22** has been achieved, the pump unit **30** is terminated and the vent port **42** is closed as shown in Figure 9 of the drawings. The chamber port **44** is then opened to allow for equalization of the pressures within the spray chamber **22** and the reservoir **50** as further shown in Figure 9 of the drawings.

If the coolant level within the spray chamber **22** has increased above a desired level, coolant from the spray chamber **22** may be input back into the reservoir **50** with the chamber port **44** open to prevent a decrease in pressure within the spray chamber

22 or without the chamber port **44** open. The chamber port **44** may then be closed to allow for normal operation of the present invention.

As to a further discussion of the manner of usage and operation of the present invention, the same should be apparent from the above description. Accordingly, no further discussion relating to the manner of usage and operation will be provided.

With respect to the above description then, it is to be realized that the optimum dimensional relationships for the parts of the invention, to include variations in size, materials, shape, form, function and manner of operation, assembly and use, are deemed to be within the expertise of those skilled in the art, and all equivalent structural variations and relationships to those illustrated in the drawings and described in the specification are intended to be encompassed by the present invention.

Therefore, the foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.